

Experimental investigation of heavy ion energy loss in dense plasma, generated by laser induced soft X-rays

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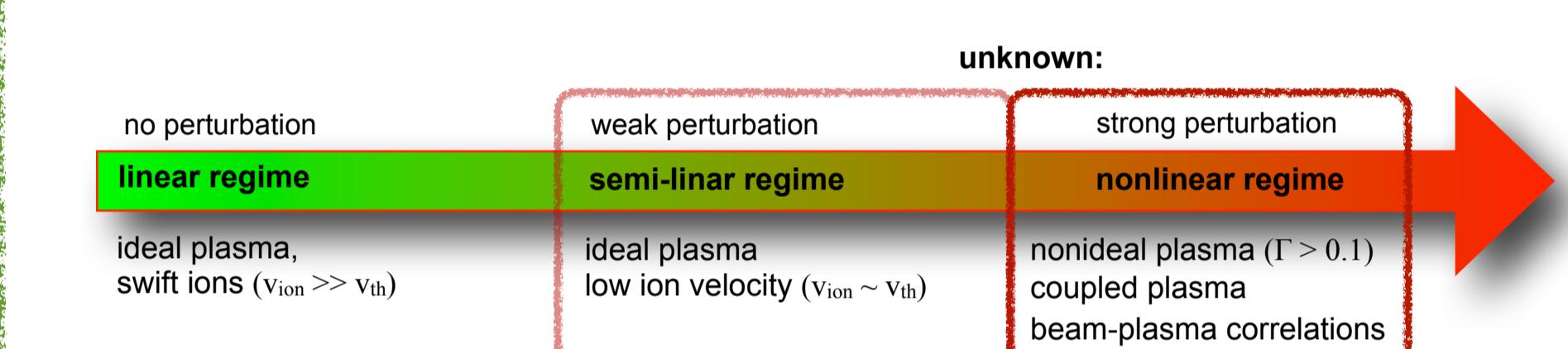
Summary & Motivation

A high-Z, mm-scale hohlraum can be heated by intense laser pulses to X-ray temperatures of tens and hundreds of eV. By placing a sample material inside, a uniform high temperature plasma state can be achieved which lasts for nanoseconds. The hohlraum prevents the hot plasma from rapid disassembly due to hydrodynamic expansion and suppresses its radiative cooling by providing high diffusive resistivity for thermal X-rays. At GSI Darmstadt double gold hohlraum targets are used for energy loss measurements of heavy ions in dense carbon plasmas. The design of the hohlraum was preceded by simulations and theoretical predictions and has been continuously optimized over the last years. The understanding of the physics in this parameter region is interesting for fusion and astrophysics. Especially the energy loss measurements are of high interest for the fast ignition approach in ICF concepts.

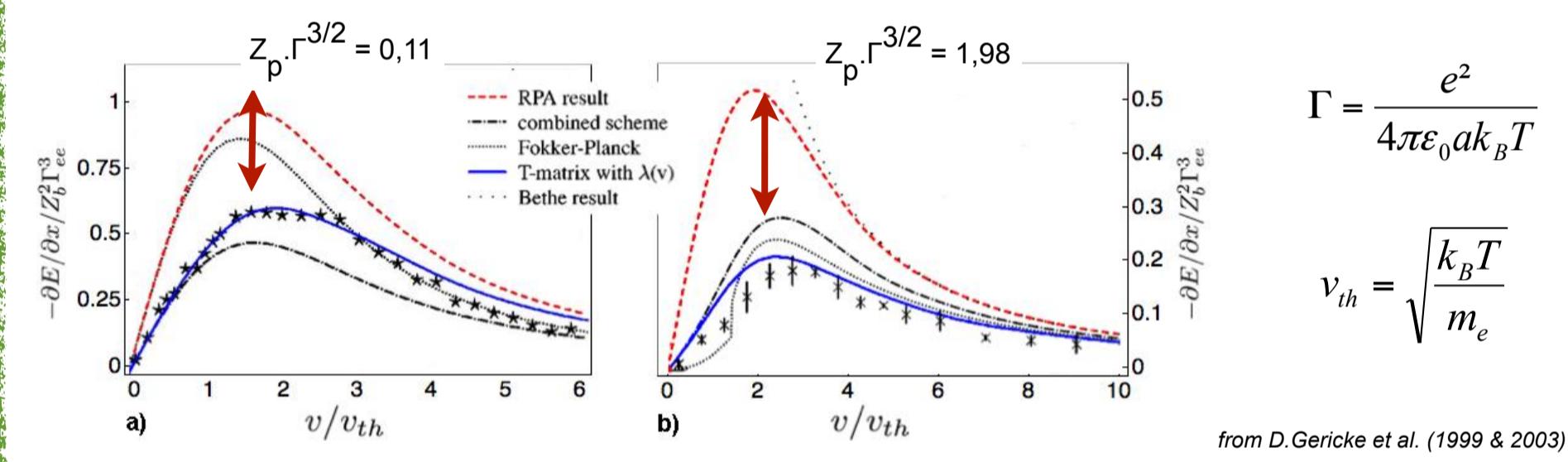
Theory:

Towards the nonlinear regime of ion stopping in plasma

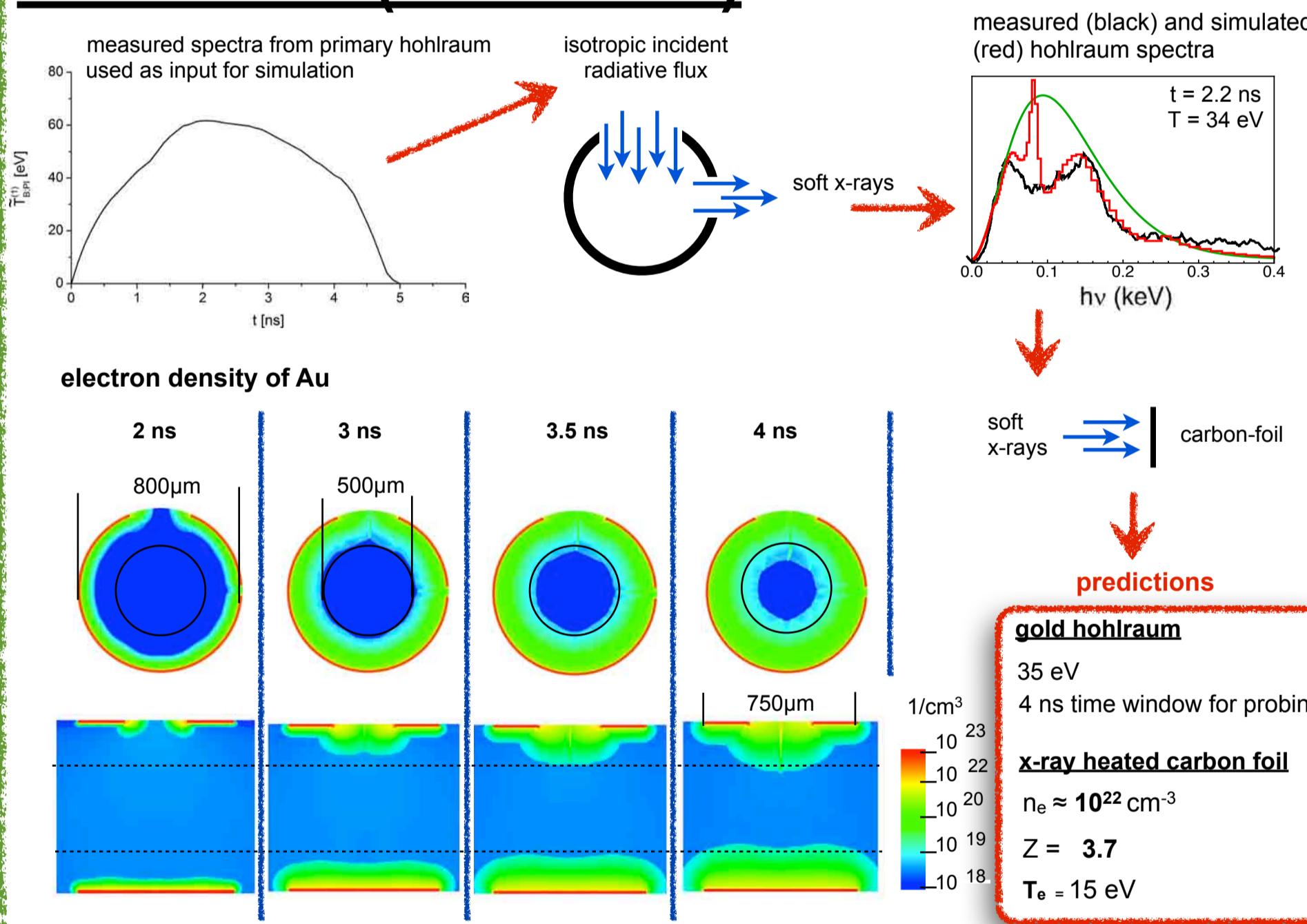
Most theories for ion stopping in matter, like the Bethe-Bloch formula are linear approaches which are no longer valid if perturbations become important (slow ions, non-ideal coupled plasma, high Z). In this nonlinear regime the few theories that exist make divergent predictions. Also, there is hardly any experimental data for energy loss in non ideal plasma and ion stopping for strong beam-plasma correlations. Within this regime a reduction of 30-50% of the stopping power is expected.



comparison of different theories

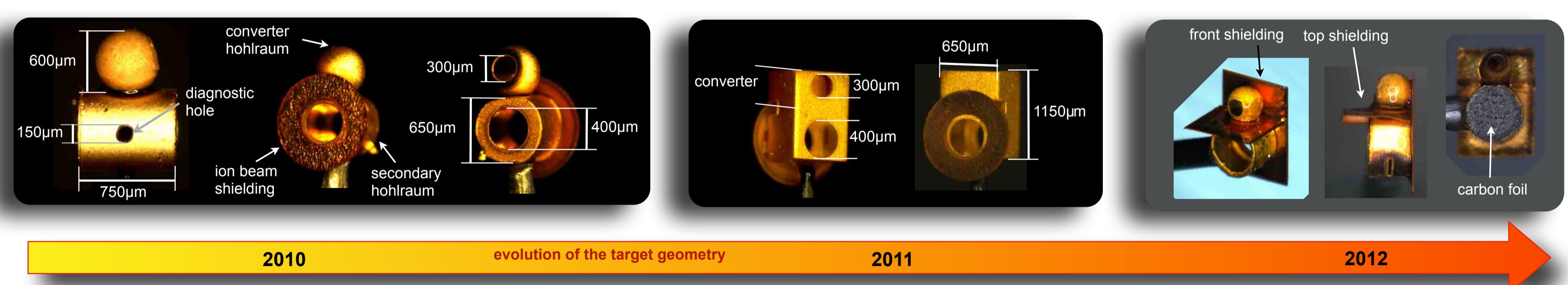


Simulation (RALEF 2D)

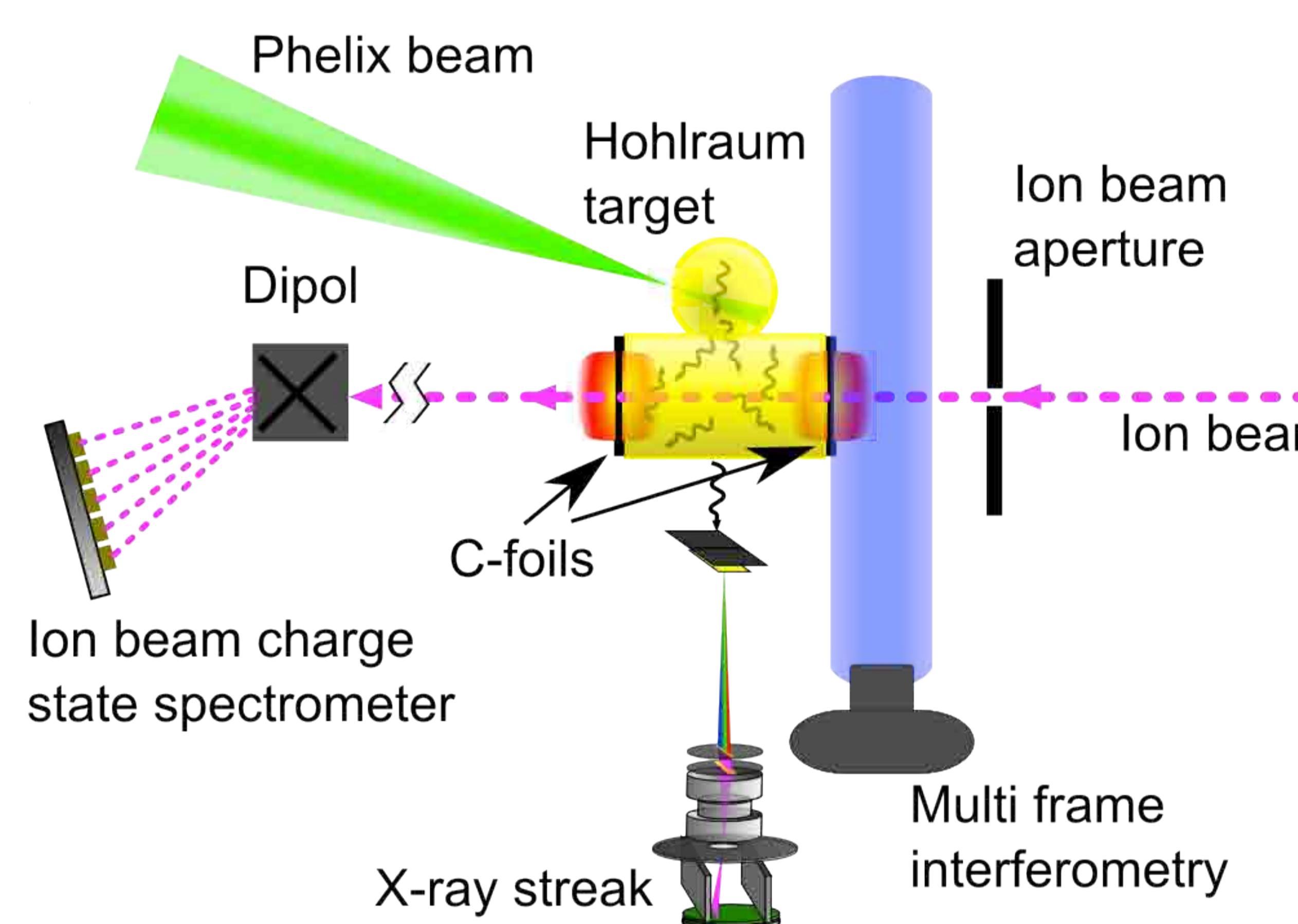


Double goldhohlraum targets

The PHELIX laser heats a primary spherical gold hohlraum. The primary X-rays heat a secondary cylindrical gold hohlraum which heat two carbon foils attached at the secondary hohlraum. The ion beam will finally probe the created dense carbon plasma. The hohlraums are produced by electroforming, lasercutting and micromechanical assembling techniques in the target laboratory of the TU Darmstadt (G.Schaumann).



Experimental setup



Laser (PHELIX):

$E = 150 \text{ J}$
 $\lambda = 527 \text{ nm} (2\omega)$
 $t = 1.5 \text{ ns} (\text{FWHM})$

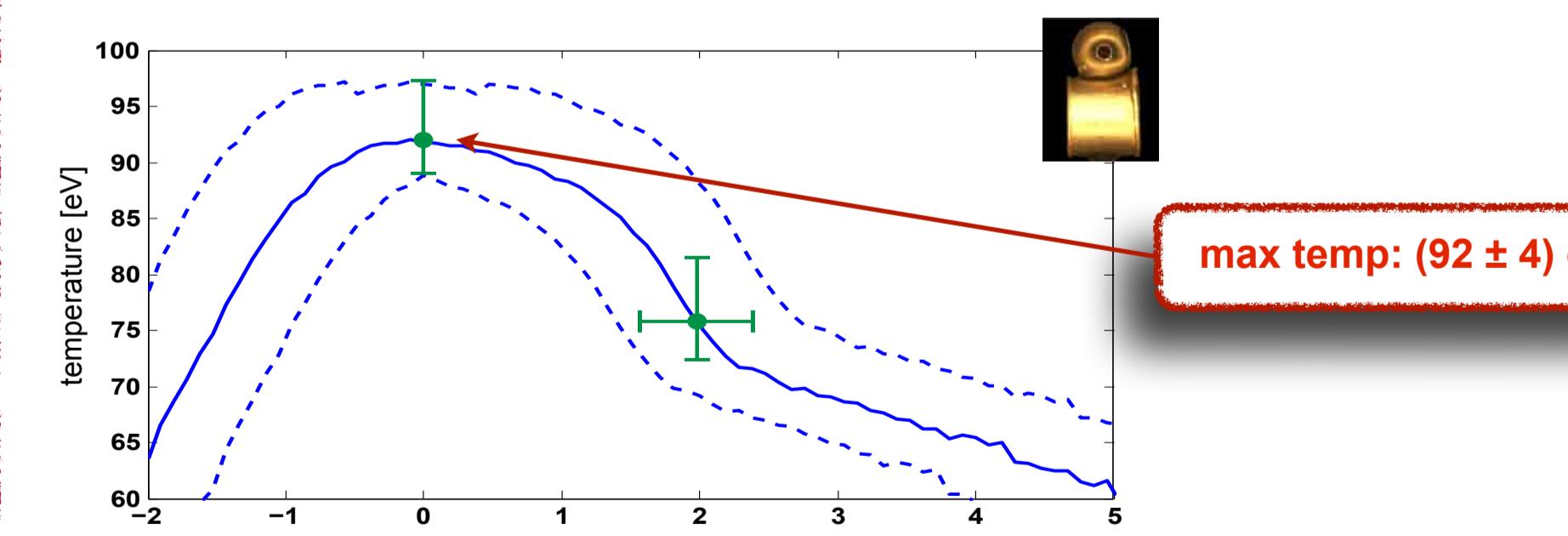
Projectile (Ion Beam):

$E = 3.6 \text{ MeV/u}$
 ${}^{40}\text{Ca}^{+17}$
500 μm beam diameter

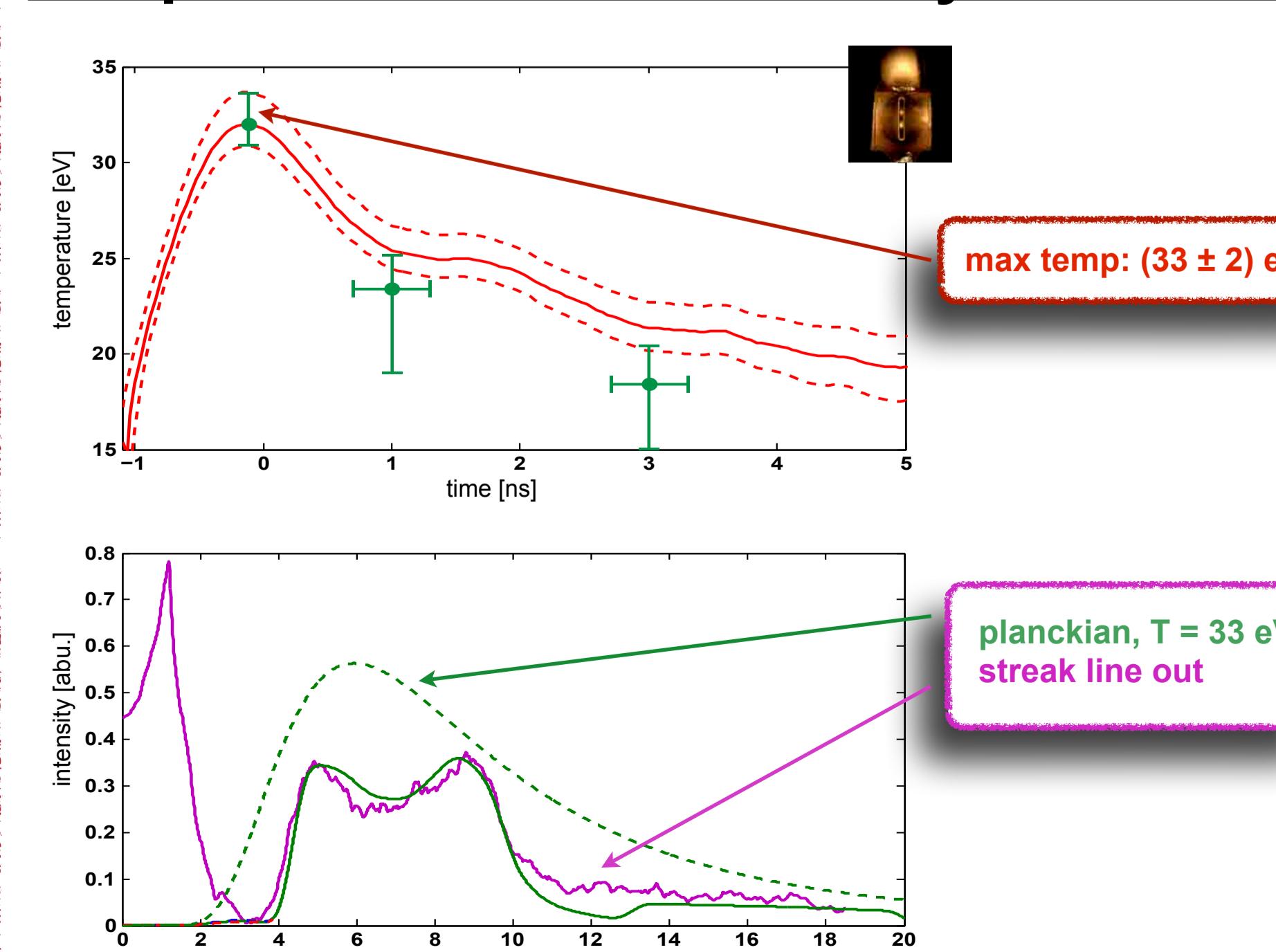
Diagnostics:

- x-ray streak (temperature)
- multi-frame interferometry (electron density, expansion)
- ion beam charge state spectrometer (charge state distribution, energy loss)

Temperature in the primary hohlraum

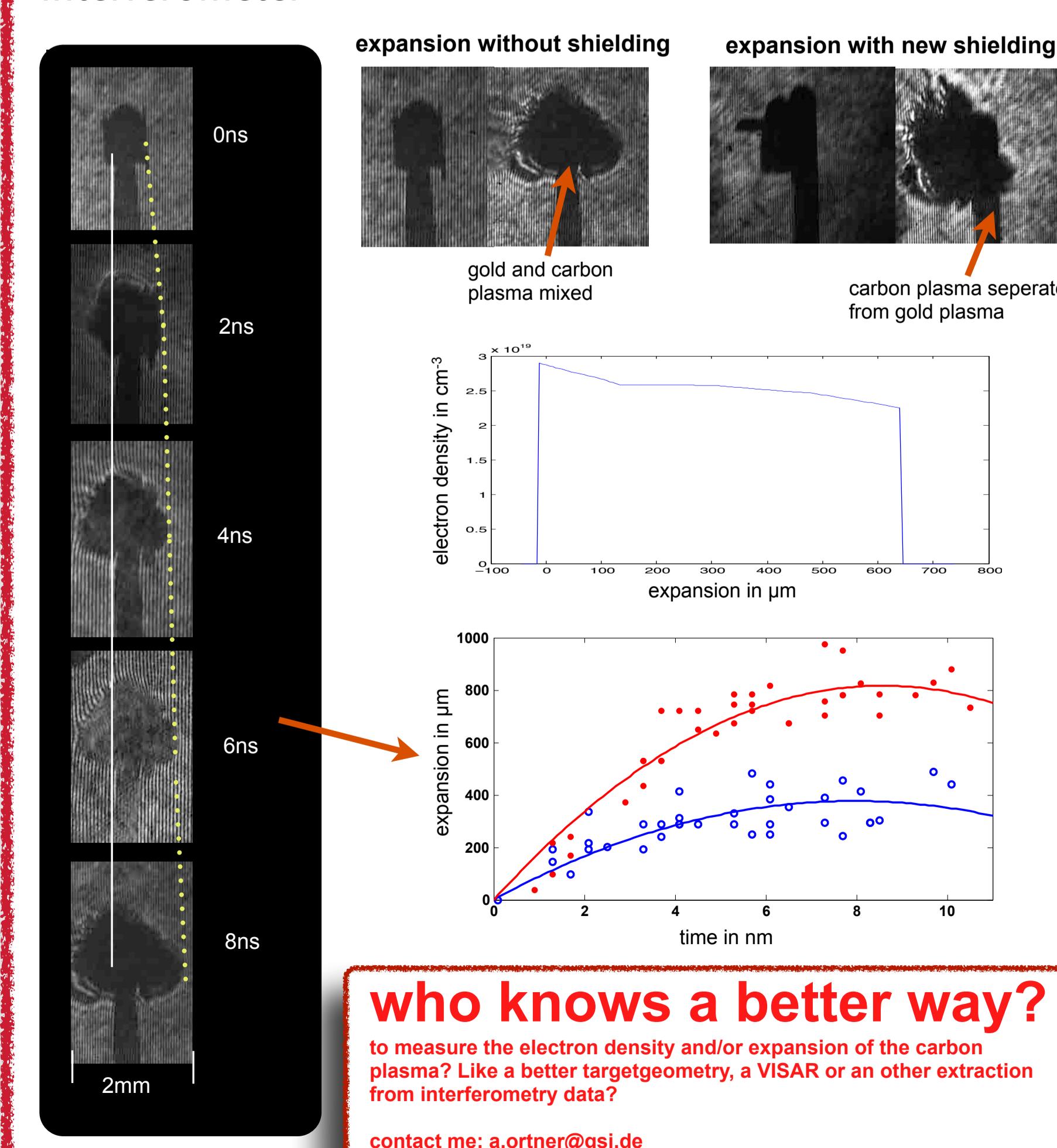


Temperature in the secondary hohlraum



Electron density and plasma expansion

A pulse train of 4 laser pulses (0.5 ns each) with a fixed Δt of 2 ns, images the plasma with a Wollaston interferometer.



Energy loss and charge distribution

